THE EFFECT OF SPECIFIC SURFACE ON THE EXPLOSION TIMES OF SHOCK INITIATED PETN*

by

Robert H. Dinegar, Richard H. Rochester, and Mike S. Millican**

University of California, Los Alamos Scientific Laboratory
Los Alamos, New Mexico

ABSTRACT

Shock initiation experiments on small pressed charges of PETN have demonstrated that the explosion times in underinitiated charges decrease with an increase in the specific surface of the explosive. This is in accord with the generally accepted proposal that the reaction in the build-up zone is heterogeneous and is governed by a surface burning law.

Initiation of the charges with shocks above a certain strength resulted in overdriven detonations. In these cases the explosion times were independent of the specific surface of the explosive.

INTRODUCTION

The specific surface of a granular explosive may under certain conditions play an important role in shock initiation. The controlling factor is the magnitude of the entering shock velocity relative to the steady-state detonation velocity in the acceptor.

If the entering shock has a velocity such that the total explosion time is equal to or less than the time required for a steady-state detonation to traverse the acceptor, it is an indication that the temperature and pressure in the shocked explosive are high enough to insure complete release of the chemical energy to the shock front. If the entering shock produces an explosion time less than the transit time for a steady-state detonation the system is overdriven. Overdrive is an unstable condition that cannot be supported by the chemical energy available in the explosive. The velocity should decay with time, due to energy losses from the system, until it reaches the steady state. The rate of this decay of overdrive might be expected to be controlled by the geometry of the system. Increasing the specific surface of the explosive to speed up the decomposition should have no effect, for once all the energy can be delivered in the required time interval, to deliver it faster will be to no avail.

On the other hand, if the shock which enters the acceptor produces an explosion time greater than that which corresponds to the steady-state detonation in the acceptor, this indicates that the temperature and pressure in the entering shock are not high enough to complete the chemical reaction at a given point before the shock has moved out of the range of influence of that point. However, if a certain degree of reaction takes place at each successive point in the charge, the temperature and pressure at the front of the wave will eventually increase to the point where the material can

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**Deceased.

react completely while within the range of influence, and a stable detonation will be achieved. The time required for the hydrodynamic disturbance to reach the steady state is called the build-up time. Under the assumption of a surface controlled reaction, the rate of the chemical reaction would be expected to be directly proportional to the magnitude of the surface undergoing reaction. The rate of change of the velocity of the hydrodynamic disturbance does not depend so simply on the chemical reaction rate. It is nevertheless clear that the build-up time would be expected to decrease with an increase in the specific surface of the reacting explosive.

EXPERIMENTAL

In this experiment the total explosion time was measured for a small-scale gap test acceptor charge. This total explosion time includes the time for build-up and the time required to traverse the rest of the charge at the steady-state velocity, if such is achieved. The build-up time in an explosive, especially in a small charge, is difficult to measure. It can, however, be inferred from the acceptor explosion time, if the steady-state velocity is reached within the charge and if this velocity is independent of the specific surface. In this experiment the steady-state detonation velocity for these acceptor charges was reached in less than one charge length and was independent of the specific surface.

The experimental arrangement is shown in Figure 1. The PETN acceptor charges were one-half inch in diameter and one-half inch long, loaded to densities of 0.75 to 0.95 g cm^{-3}, in molded plastic holders. Although only the data for the higher density are reported, the lower gave similar results. The initiating shock strength was varied by changing the thickness of the brass[1] attenuator from zero to 0.250 inch. This corresponded to a change of pressure in the brass from 350 to 90 kbar.[2] The donor charges were 0.206 inch long by 0.300 inch diameter plastic-bonded cyclotrimethylenetrinitramine (RDX) pellets of 1.6 g cm^{-3} density initiated by low density PETN which, in turn, was set off by an exploding wire.

The range of specific surfaces investigated was about 3,000-12,000 $cm^2\ g^{-1}$. Although the data for only two (3,900 and 11,650 $cm^2\ g^{-1}$) are reported here, a third (ca. 8,000 $cm^2\ g^{-1}$) gave proportional intermediate results. The different specific surfaces were obtained by varying the conditions under which the PETN was precipitated from acetone by the addition of water. Experiments run with ball-milled material gave the same results as the precipitated material when the specific surfaces were the same. Specific surfaces were determined by a permeameter, an instrument that measures surface per unit mass by permeability methods.[3]

Acceptor explosion times were determined in the following manner: (1) rotating mirror camera records of the light emitted from the end of the donor and from the end of the acceptor gave the average time required for the wave to travel through both the brass attenuator and the acceptor charge; and (2) electronic switch measurements on the donor charge and on the donor-charge/brass-attenuator combination gave the average time spent by the shock in the brass attenuator. The difference between measurements (1) and (2) is the time through the acceptor charge which we have called the explosion time (t_{exp}).

DISCUSSION OF RESULTS

(a) Explosion Times

The data are plotted in Figure 2. With no brass attenuator in the system the donor charge initiated PETN of either specific surface so that the detonation traversed the acceptor in a time shorter (by 5%-6%) than that calculated on the basis of the steady-state detonation velocity throughout the charge. No specific surface effect was observed.

As the thickness of the brass attenuator was increased to 0.030 inch (270 kbar pressure) the overdrive dropped to zero as evidenced by the fact that here the explosion times were 2.56 μsecs - a value numerically equal to the time calculated using the steady-state detonation velocity of 4,960 m sec^{-1} and the charge length of one-half inch.

For brass attenuator thicknesses greater than 0.100 inch a clear cut separation of the explosion times was observed on a specific surface basis. The PETN pressings with the larger specific surface had the shorter times, which is attributed to a greater rate of reaction in the build-up zone with the larger specific surface.

For brass attenuators near the 50% fire point, some acceptors failed to detonate and the explosion times of the two PETN samples could not be compared properly. The 50% brass thickness has been determined[4] as 0.270 inch (80 kbar pressure) for the larger specific surface material and 0.310 inch (65 kbar pressure) for the smaller specific surface sample.

(b) Detonation Velocities

Variations of the build-up times can be inferred from observed variations of the explosion time measurements if information is available on the steady-state detonation velocities in these particular pressings of PETN. Such steady-state velocities have been measured for the two samples of PETN used in these experiments and no change with specific surface has been found. The explosion times were determined as a function of charge length by observing the light signals from the ends of charges of various lengths with a rotating mirror camera. Apparently the steady-state detonation had developed before the end of the first one-half inch of charge. A least-squares fit was made to the time-distance data shown in Figure 3. The calculated values of the steady-state detonation velocities with their standard deviations are 4,929 ± 37 m sec^{-1} for the larger specific surface and 4,995 ± 57 m sec^{-1} for the smaller, which are the same within the limits of experimental error.

CONCLUSION

It has been demonstrated that the explosion times of underinitiated small pressed charges of PETN decrease with an increase in the specific surface of the explosive. This decrease is believed to occur in the unstable build-up zone that precedes steady-state detonation and is explainable in terms of a surface-burning reaction.

Overinitiation of the charges of PETN gave rise to explosion times that were shorter than those calculated using the steady-state detonation velocity. These explosion times were independent of the specific surface and might be expected to be controlled by the geometry of the system.

REFERENCES

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2. J. O. Johnson, Private communication.
3. R. M. Lea and R. W. Nurse, J. Soc. Chem. Ind., 58, 277 (1939).
4. R. H. Dinegar, R. H. Rochester, and M. S. Millican, Effect of Specific Surface on Shock Sensitivity of Pressed Granular PETN this session.

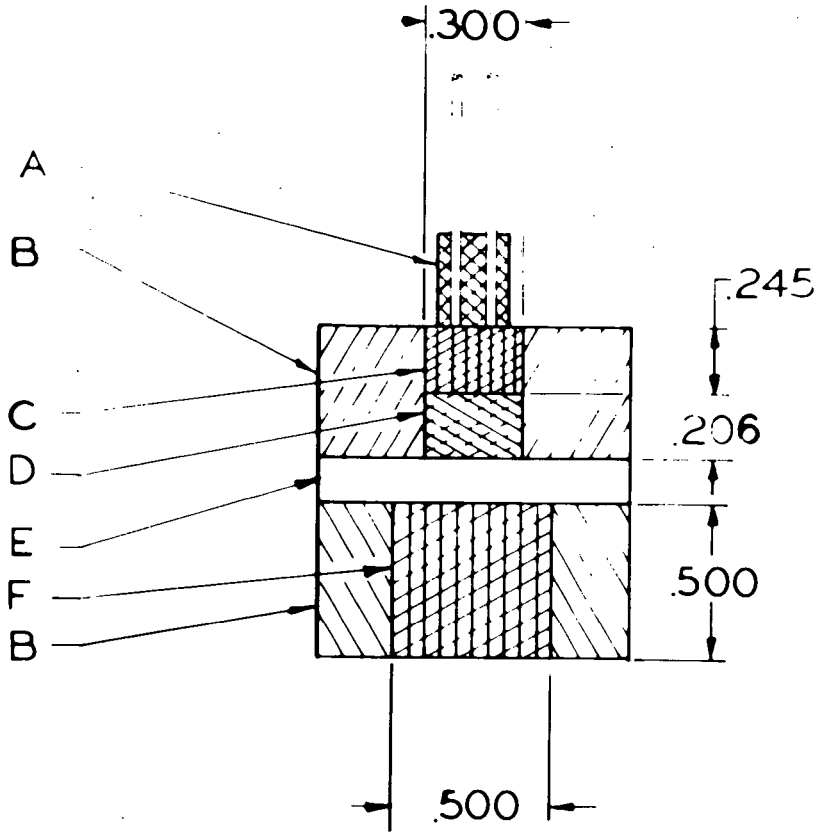

Figure 1

SMALL-SCALE GAP TEST ASSEMBLY

A = Exploding wire assembly; B = Plastic holders; C = PETN initiator; D = Plastic-bonded RDX donor; E = Brass attenuator; and F = PETN acceptor (test) charge.

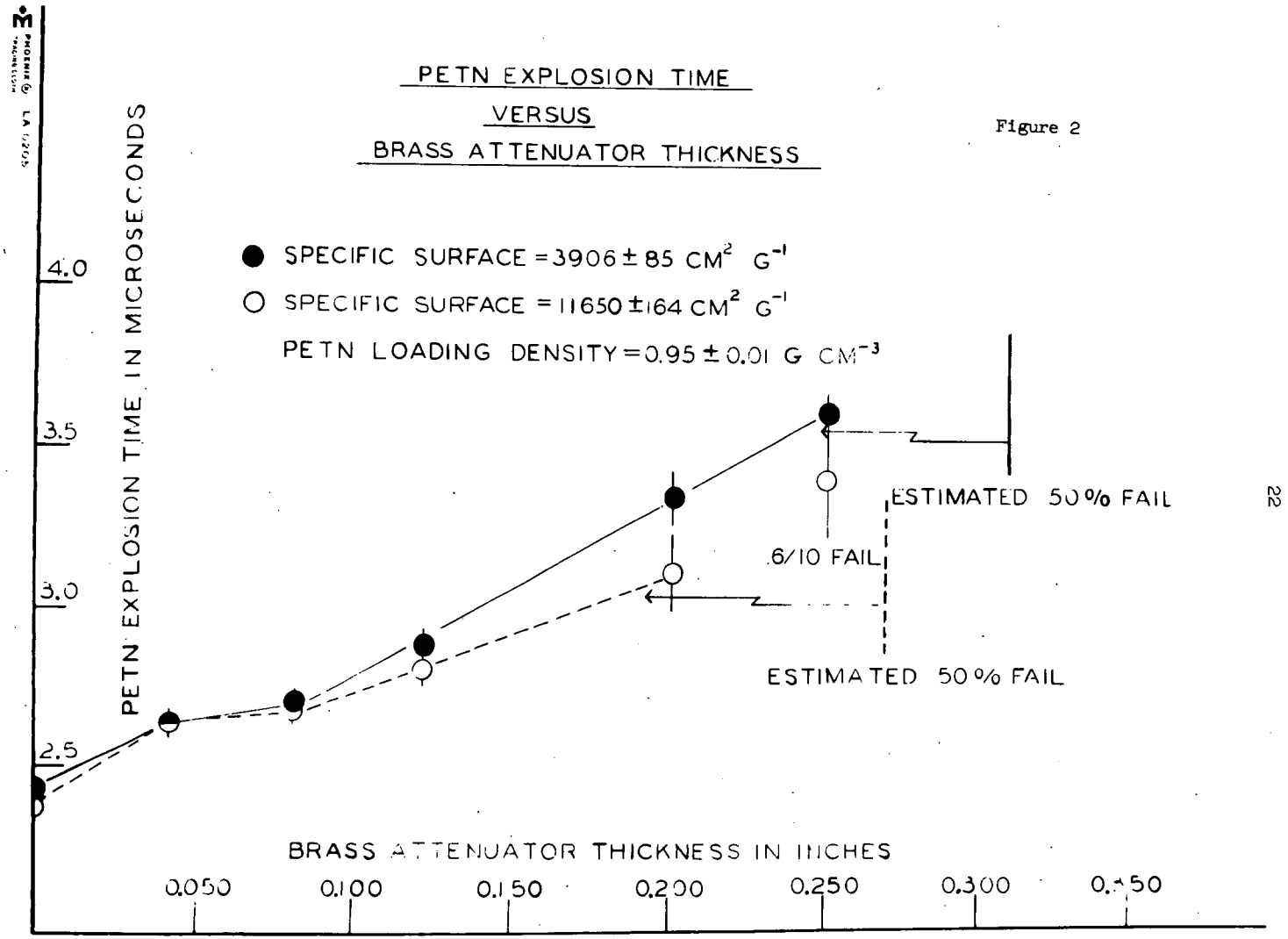
PETN EXPLOSION TIME
VERSUS
BRASS ATTENUATOR THICKNESS
SPECIFIC SURFACE = 3906 ± 85 CM² G⁻¹
SPECIFIC SURFACE = 11650 ± 164 CM² G⁻¹
PETN LOADING DENSITY = 0.95 ± 0.01 G CM⁻³
PETN EXPLOSION TIME IN MICROSECONDS
4.0
3.5
3.0
2.5
ESTIMATED 50% FAIL
6/10 FAIL
ESTIMATED 50% FAIL
BRASS ATTENUATOR THICKNESS IN INCHES
0.050
0.100
0.150
0.200
0.250
0.300
0.350

Figure 2

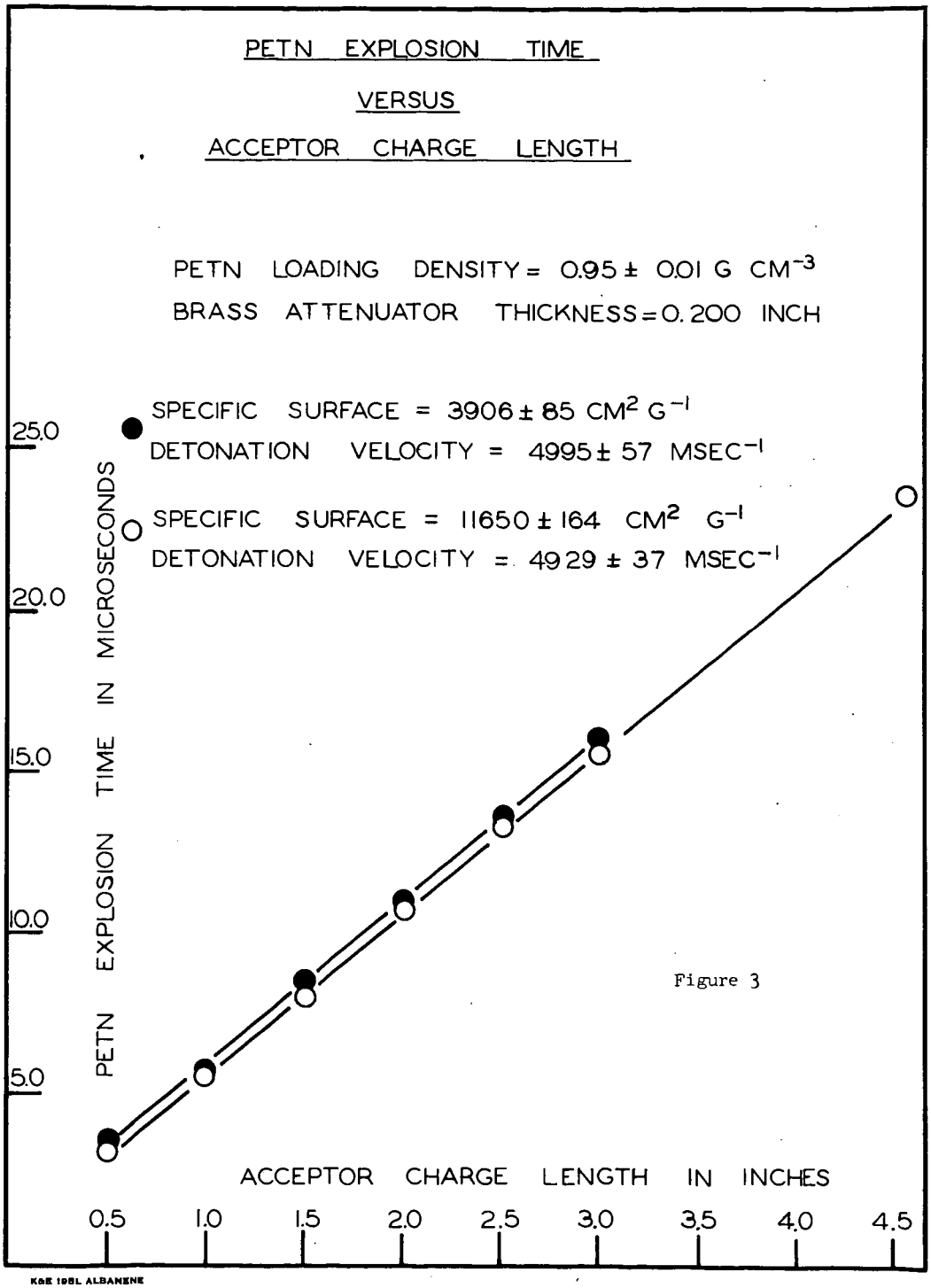
PETN EXPLOSION TIME
VERSUS
ACCEPTOR CHARGE LENGTH
PETN LOADING DENSITY = 0.95 ± 0.01 G CM⁻³
BRASS ATTENUATOR THICKNESS = 0.200 INCH
SPECIFIC SURFACE = 3906 ± 85 CM² G⁻¹
DETONATION VELOCITY = 4995 ± 57 MSEC⁻¹
SPECIFIC SURFACE = 11650 ± 164 CM² G⁻¹
DETONATION VELOCITY = 4929 ± 37 MSEC⁻¹
PETN EXPLOSION TIME IN MICROSECONDS
25.0
20.0
15.0
10.0
5.0
ACCEPTOR CHARGE LENGTH IN INCHES
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
KOE 1981 ALBANENE

Figure 3